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PROGRESS REPORT OUTLINING WORK

ON

CONTRACT Nonr-248(37) - NR 083-038/7-28-52

FOR

PERIOD ENDING 15 JUNE 1953

Progress Report Outlining Work

on

Contract Nonr-248(37) - NR 083-038/7-28-52

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Period Ending 15 June 1953

Contractor: The Institute for Cooperative Research of The Johns Hopkins University Baltimore, Maryland

Participating: F. Middleton, Wen-Hsiung Li, R. Kerr, C. F. Miller

ESTUARINE CURRENT METER CONTRACT

PROGRESS REPORT
FOR PERIOD ENDING 15 JUNE 1953

The planning of the "Cantilever-Type" current meter has proceeded in the direction indicated in the last progress report; that is, the "Y"-Type Position Convectron has been replaced by resistance wire strain gauges as a cantilever load detector.

In sensing the velocity with a circular disc attached to the end of a cantilever, a disc 8.5 inches in diameter and a 2-foot cantilever with 3/8" x 1/16" cross-section are used. With this arrangement, the strain produced at the fixed end of the cantilever by a current of 0.1 ft./sec. is about 30 x 10^{-6} inches which can be measured with reasonable accuracy with strain gauges. To limit the deflection of the cantilever under high velocities, a "cubic" spring (one with resistance proportional to the third power of the deformation) at the back of the disc was suggested. However, such a spring is difficult to make, and is easily put out of working order by clogging between the coils of floating debris. Instead, three cantilevers with various stiffness are used, as shown in the Figure 6a. With this arrangement, the maximum deflection of the cantilever is 6 inches under a velocity of 5 ft./sec. Barring disturbances due to turbulence in the flow and movement of the support, the error of observation on velocity due to an error in strain measurement of 10^{-6} inches is considerably less than 0.006 ft./sec. for velocities up to 1 ft./sec., and is less than 0.012 ft./sec. for velocities from 1 ft./sec. to 5 ft./sec.

Because of the high degree of sensitivity required in this application, a servo-balance system is being used rather than an amplifier-meter arrangement. The components for this system have been procured, and can be seen in Figure 1a. The arrangement shown in the photograph does not represent the final form of the instrument, but has been made to permit convenient checking of system characteristics such as balance sensitivity, response time, noise, and drift.

The bar at the bottom of the photograph is the brass cantilever beam being used for these bench tests. It is not the same as the final cantilever in either section or length, but serves the purpose of producing strain in the four gauges attached near one end of the bar. These gauges are connected in series to produce one-half of a Wheatstone bridge circuit. The remainder of the bridge circuit, including a ten-turn Helipot, is contained in the aluminum box on the right side of the assembly at the top of the photograph. The Helipot shaft extends through the mounting plate, and is geared to the servo motor and to the revolution counter. The counter indicates the balance position of the servo system, and therefore the deflection of the cantilever beam. A camera will be used in the final instrument to photograph this counter.

Figure 2a shows the components of the compass system to be used to indicate the direction of the current in the final instrument. The unit on the right is the magnetic compass, and will be housed in the current sensing head. The other two components, the compass remote indicator and the inverter, will be placed in the anchor in the final instrument. The inverter is driven by 24 volts D.C., and delivers 400 c.p.s. excitation to the synchro transmitter in the compass and the receiver in the indicator. The indicator will be placed in the field of view of the same camera that photographs the revolution counter.

Figure 3a is a photograph of the equipment associated with the present work being done on the ultrasonic current meter. The water tank is at the right in the photograph. Figure 4a is a closeup of the experimental transducers as they are supported in the water. Figure 5a shows the principal electronic chassis of the ultrasonic current meter.

This chassis contains the transmitter crystal driving oscillator, the receiving crystal channel, the comparison channel, and the phase meter. Reference was made in previous progress reports to a final report by R. K. Brown of the University of Michigan on the "Design and Development of an Underwater Sound Velocity Meter". The circuits used in the present chassis are, with some significant changes, similar to the circuits discussed in that report. One of the principal differences is that we are using 1 megacycle for the ultrasonic frequency. It was felt that at this high a frequency the most important consideration would be the packaging problem, so that there was little information to be gained by building a breadboard. This first model is a miniaturized version with a shape most likely to fit the instrument head that is now being considered.

The transducers are the same ones described in the last progress report. No changes have been found necessary after many hours of operation and many weeks of submergence. However, some refinements in the final transducers will permit more simple installation of the crystals and cables.

The ultrasonic current meter has been successfully operated indicating a phase difference introduced by changing the spacing between the transducers. Several problems to receive attention as soon as time permits are:

1. A circuit to inject accurate increments of phase shift in the transducer circuits.
2. A switch to interchange the transducer functions.
3. A power supply package to be contained in the anchor.
4. A current velocity and direction recorder to be contained in the anchor.
5. An operation "programmer".

Two brief discussions will be made; one to describe the "programmer" operation, and the other to describe the meter operation.

In previous reports it was pointed out that the ultrasonic signal must be transmitted upstream and downstream. The primary reason for this is that static head pressure, temperature, and salinity of the water all have the same affect as water velocity on the phase difference between the transmitted and received ultrasonic signal. The first three effects will be the same whether the signal is transmitted upstream or downstream, while the water velocity induced phase difference will be the same in magnitude, but opposite in direction when the direction of transmission is reversed.

The "programmer" will be controlled by a clock, starting the equipment every half hour. After a suitable warm-up period, the ultrasonic signal will be transmitted upstream and down, perhaps two or three times in each direction, and the phase difference will be recorded continuously. The compass indication will be recorded simultaneously, afterwhich the "programmer" will de-energise the equipment.

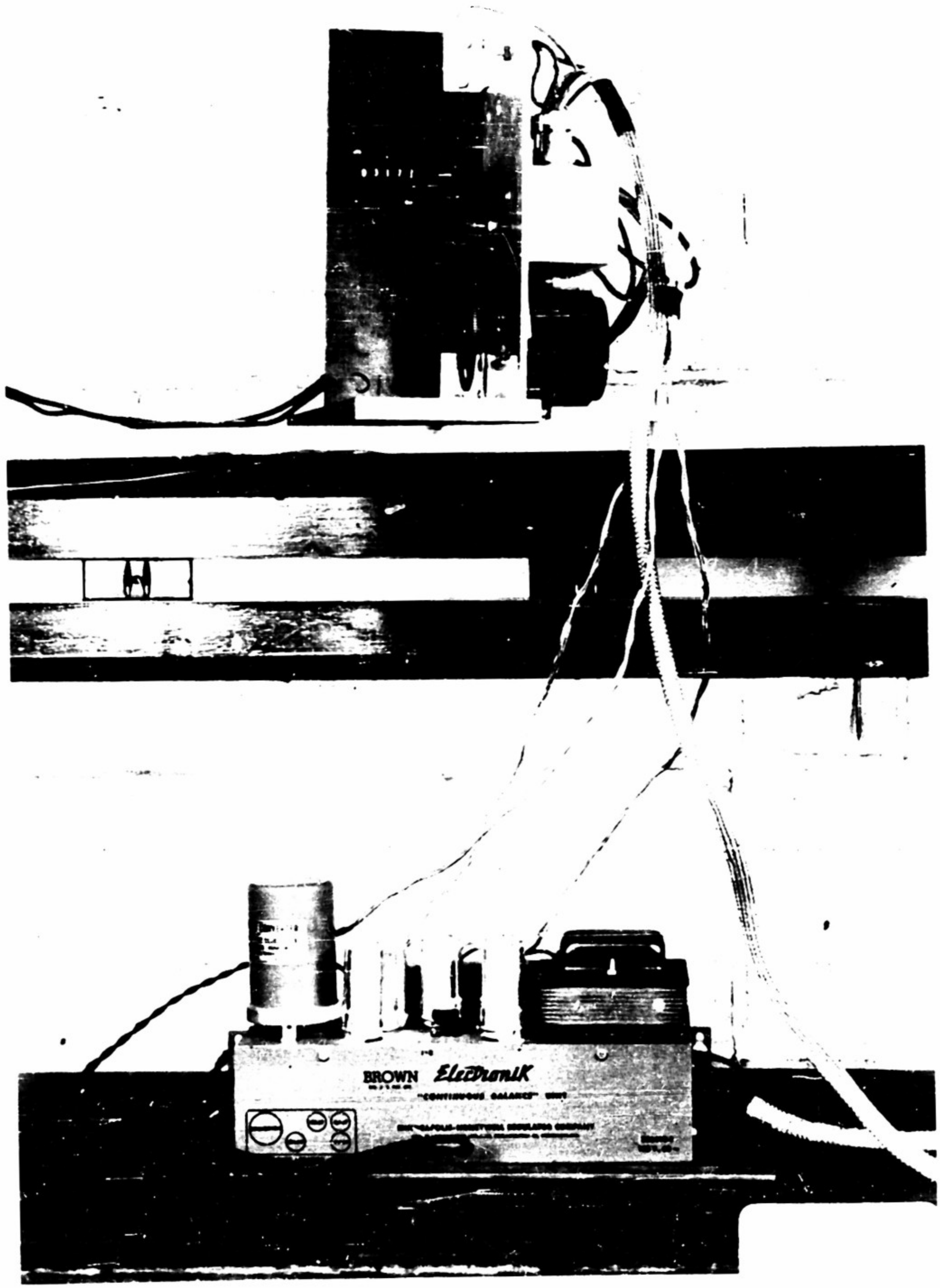
When the "programmer" starts the meter, the crystal-controlled oscillator drives the transmitting transducer and the reference channel mixer at a frequency of 1 megacycle. The receiving transducer signal is fed to a one-stage amplifier and thence to the signal channel mixer. Both of these mixers are controlled by a 1.008 mc. crystal, and so the output of both channels is an 8 kc. signal. These two 8 kc. signals have maintained the phase difference present in the 1 mc. signals, and are then amplified and clipped to the point where they appear as steep front square waves. At this point, the signals are fed to a bi-stable circuit wherein provisions are made to indicate the proportion of the time that the circuit is in either of the stable states. This information is available in the form of a D.C. current, the magnitude of which is proportional to the phase difference between the transmitted and received ultrasonic signals. There will be two of these current magnitudes; one for upstream and one for downstream transmission. The difference between these two currents will then be proportional to the water velocity.

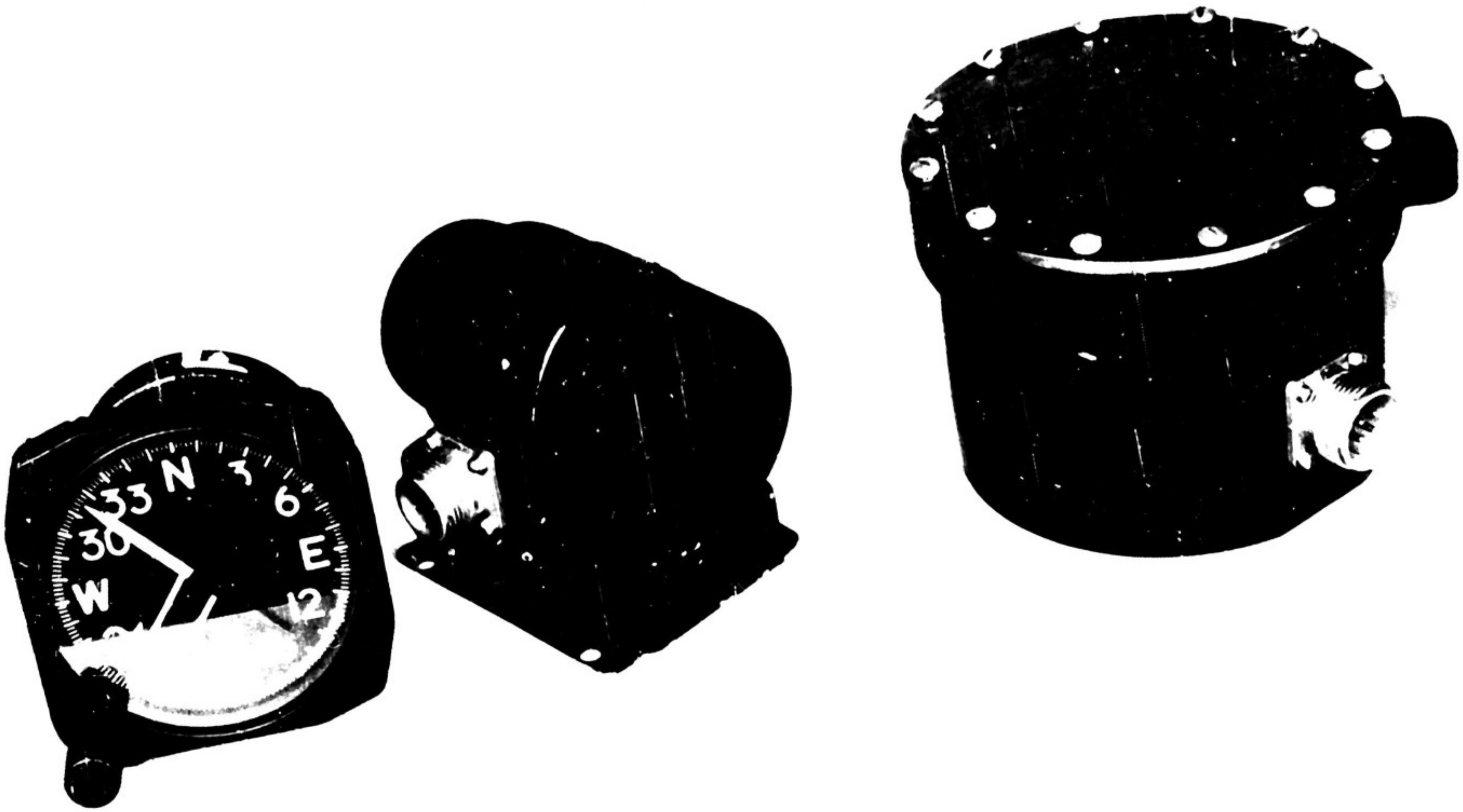
Support Housing:

As stated in previous reports, the instrument should not be suspended from the boat or a float so as to avoid induced currents due to movement of the boat or the float. The instrument is to be attached to a support with an overall density which is less than water. This support is connected by a wire to a removable anchor resting at the bottom of the estuary.

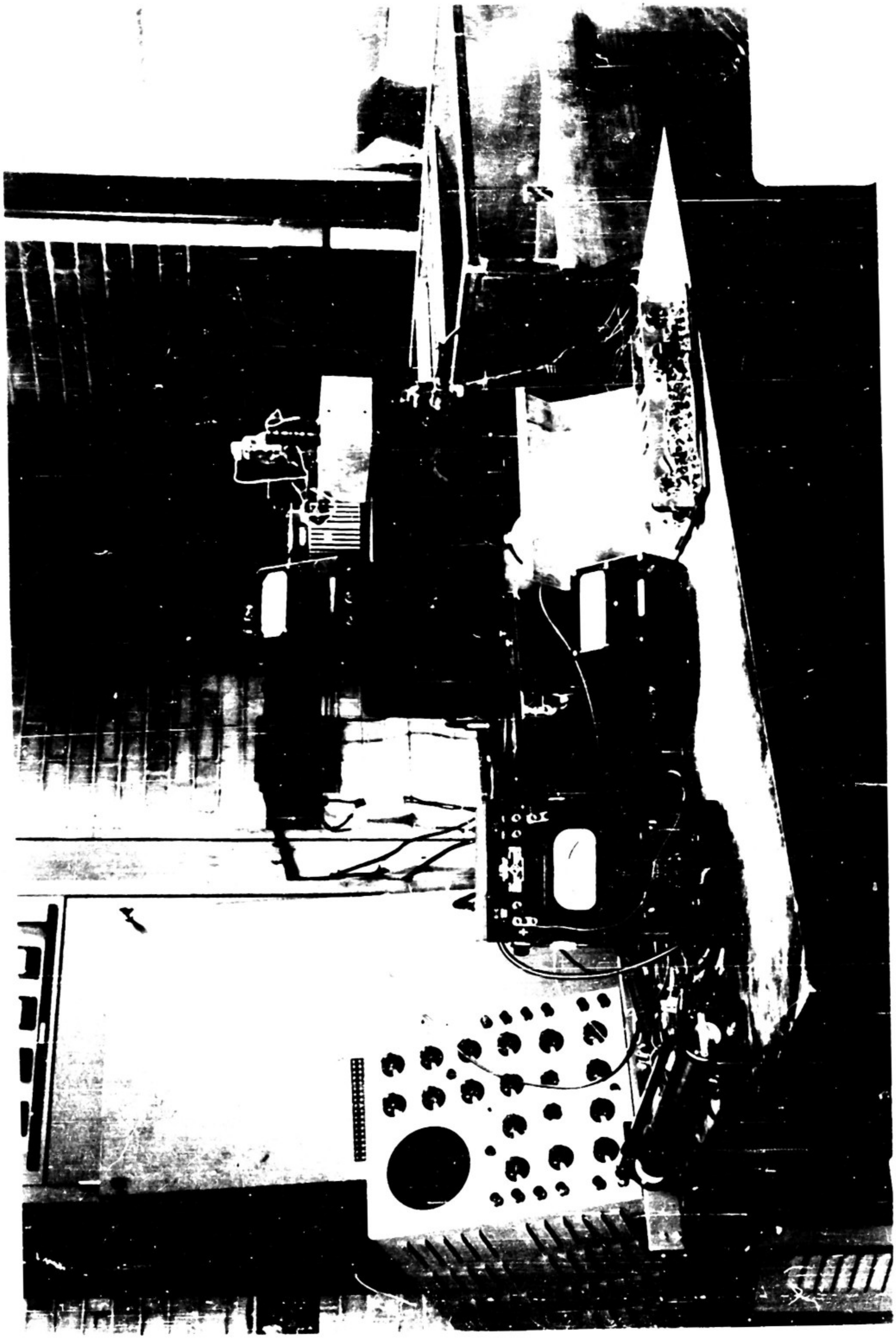
For this support, a paravane was originally suggested. This arrangement will maintain a practically fixed position of the instrument, as reported previously. However, it has been found that in order to provide space for instruments within the paravane, and at the same time to maintain its stability against possible current disturbances, a paravane weighing about 300 pounds would be required.

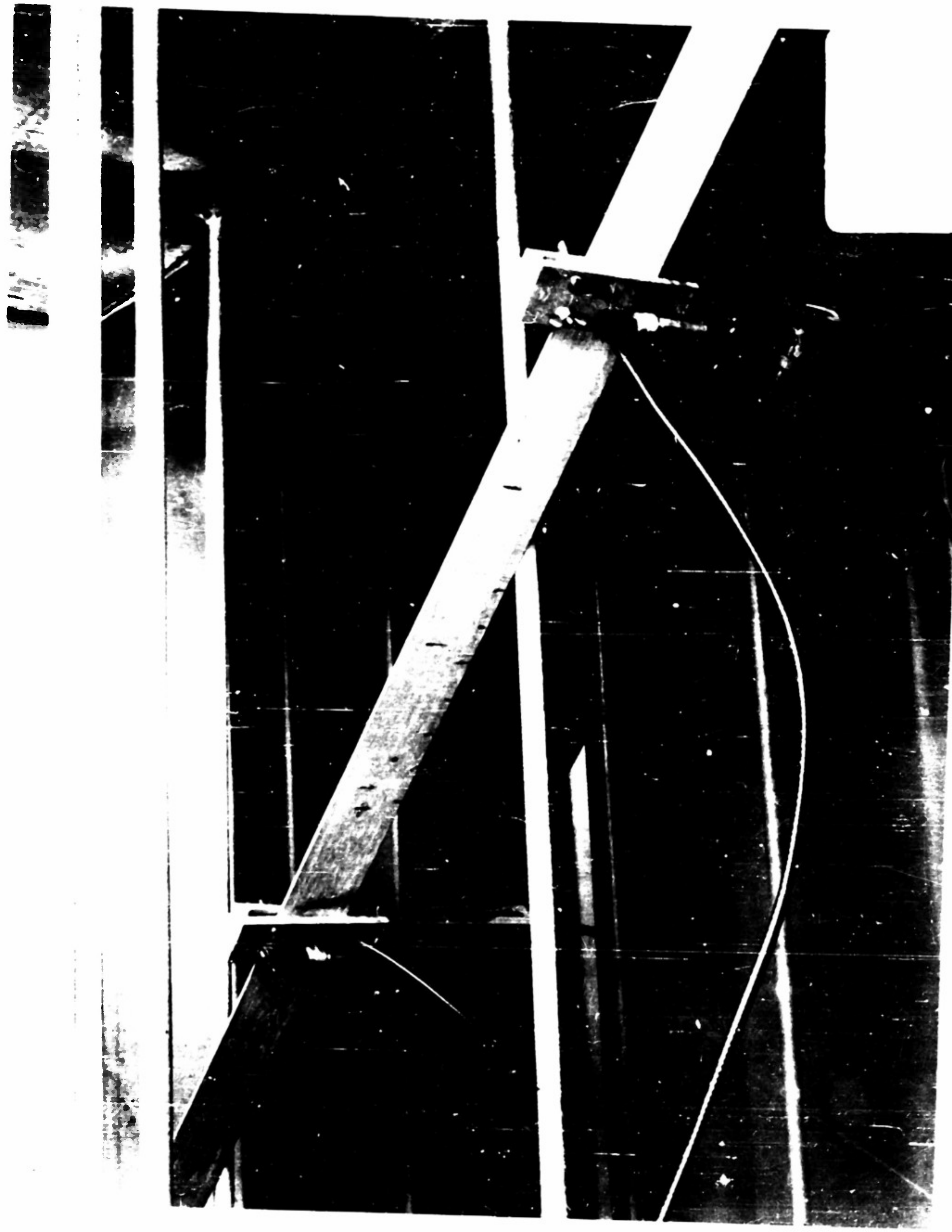
In view of the undesirable weight of the paravane, other shapes for the support have been investigated. It has been found that a hollow body of revolution with horizontal and vertical stabilizing fins will answer the purpose (See sketch, Figure 6a). Although this support will drift more than a paravane would (maximum angle between connecting wire and the vertical being less than 10 degrees), its weight is less than 100 pounds, which can be handled by one person without great difficulty.

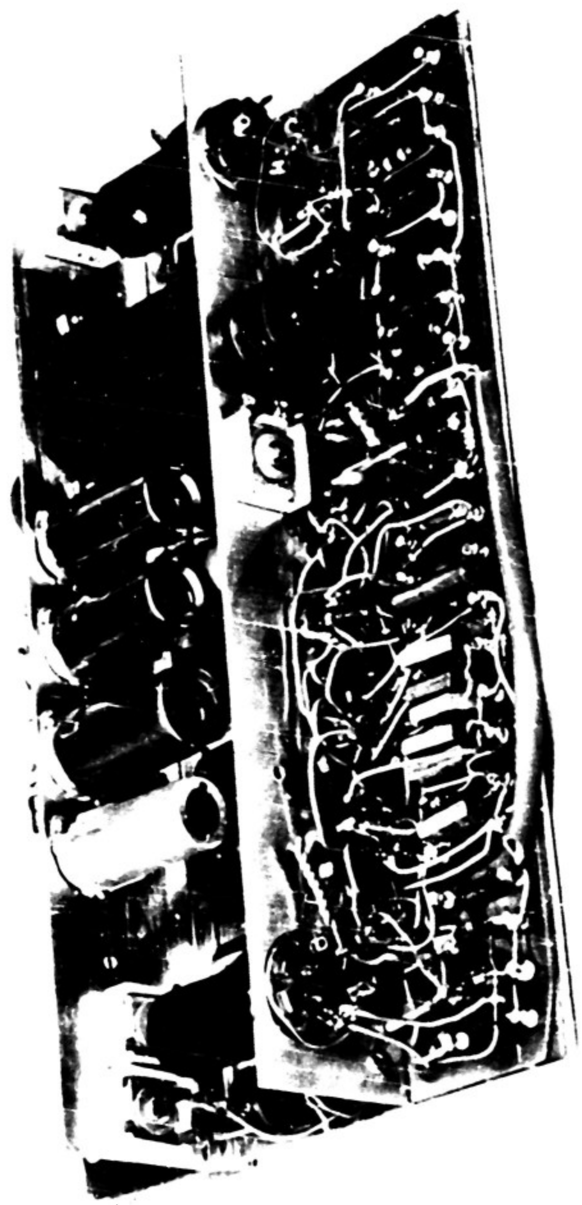

BROWN
ElectroniK
"CONTINUOUS BALANCE" UNIT

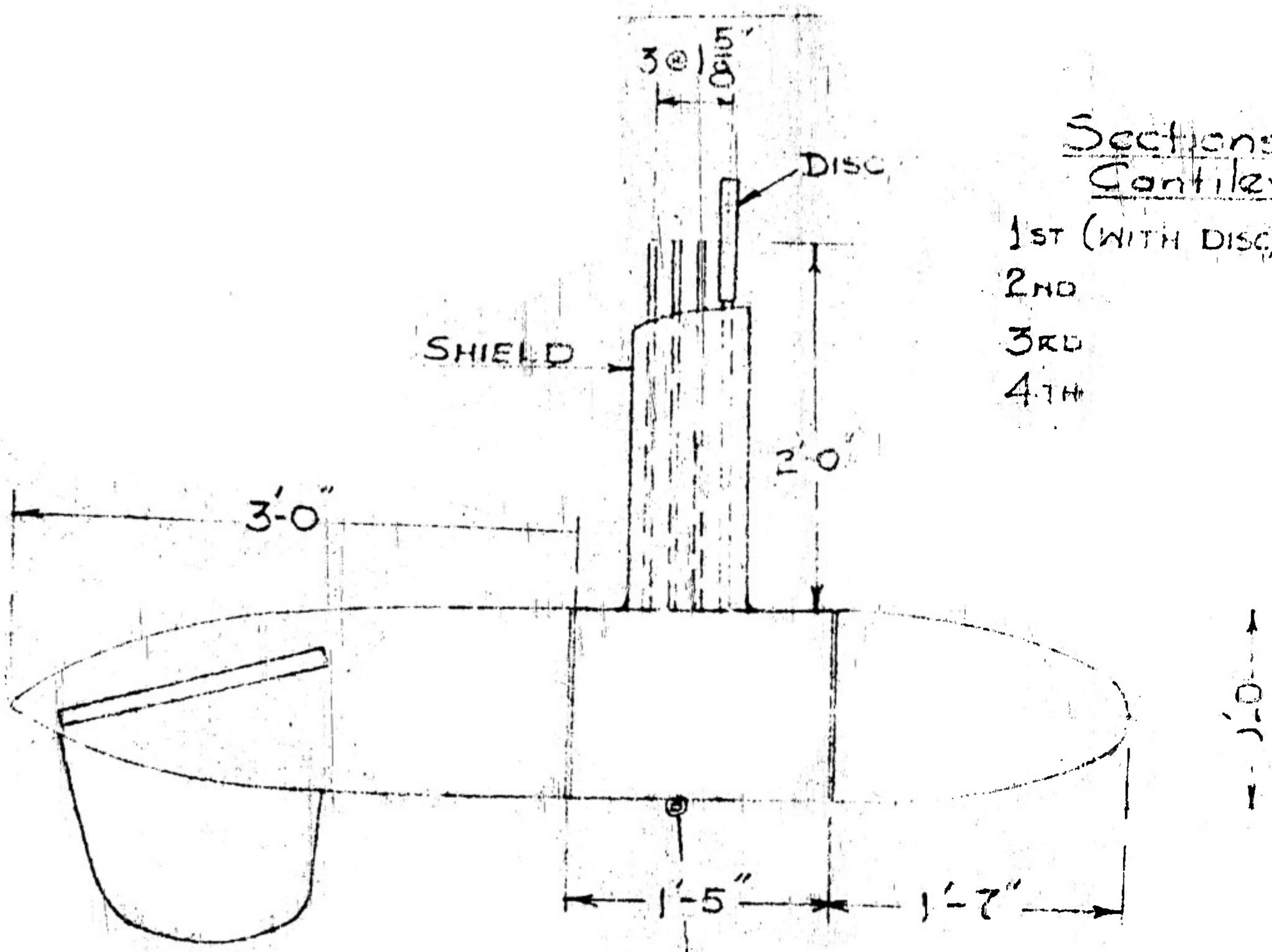


33
N
3
6
30
E
W
12









Sections of Cantilevers:

1ST (WITH DISC):	$\frac{1}{16}'' \times \frac{3}{8}$
2ND	$\frac{1}{8}'' \times \frac{7}{16}$
3RD	$\frac{3}{16}'' \times \frac{27}{32}$
4TH	$\frac{1}{4}'' \times \frac{15}{16}$

FIG 6a

APPENDIX I

CONVECTRON PERFORMANCE

Two Y-Type Position Convectrons were procured from the manufacturer for the purpose of determining their suitability for use in the drag-disc current meter. A fixture was designed and built so that both static and dynamic tests might be made. A photograph of this fixture may be seen in Figure 1.

A steel shaft is mounted in ball bearings and supported by a rigid "A" frame. A plastic Convectron housing box is mounted on one end of this shaft and a large spur gear near the other end. The plastic box was required to shield the Convectron from random air currents. The gear was used to drive a smaller gear attached to a three-turn Helipot shaft. A plane mirror was mounted on the gear-end of the shaft.

A line source of light was focused on this mirror from a distance of 17 feet and reflected to a vertical scale on a wall near the light source. This arrangement provided an optical lever 34 feet long. A translation of the line image on the scale of 1/16 inch could be readily detected, and this corresponds to an angle of 0.5 minute of arc. This optical system was used to measure the inclination of the Convectron for all of the static data in this report.

The Helipot was installed to have a means of measuring the inclination of the Convectron for dynamic tests, since the optical system could not be so used. The Helipot provided an inclination resolution of 0.1 degree of arc which was sufficient for this type of test. No dynamic test data are included in this report for reasons to be discussed presently.

The Convectron is a simple hot wire device and consists of two balanced sections of filament enclosed in a glass envelope filled with an inert gas. The two sections of filament form a "V" with a 90 degree vertex angle. The plane of the Convectron is mounted normal to the axis of the rotation (or inclination) to be measured, and is balanced with the "V" vertical, or with each section of the filament inclined at approximately 45 degrees to the vertical.

Deviation from this balanced position will cause unequal convection cooling rates in the two filament sections, and a resulting unbalance in the filament resistance appears as a Wheatstone bridge output.

A test was made on the Convectrons to determine the dependence of the output on the magnitude of the excitation voltage. The first tests were made using 1,000 c.p.s. and 60 c.p.s., but the null voltage was excessive in both cases. For this reason D.C. excitation was used throughout the following tests.

The families of curves in Figures 2 and 3 are the result of this test on Convectrons numbers 1 and 2, respectively. A fixed resistor was used in series with the Convectron bridge output so that a milliammeter with a 4 inch scale could be used as an indicator. For this reason, the ordinate of these curves is bridge output current. The data were obtained by setting and maintaining the excitation at a given level while varying the inclination of the Convectron. This was done in 1/2-volt steps at voltages between 7 and 12 volts. Each curve represents the Convectron bridge output at a given inclination as a function of applied voltage.

The most significant conclusion to be drawn from these curves is that there is no excitation voltage for which the rate of change of bridge output with applied voltage is the same at all inclinations. This would be an undesirable feature because of the difficulty of maintaining a fixed excitation voltage.

Another conclusion that is apparent from these curves is that Convectron sensitivity is very much dependent on applied voltage and has a pronounced peak at approximately 10 volts. These curves also indicate that the null inclination is a function of the applied voltage magnitude. For this reason another test was run wherein the inclination at null was measured for different applied voltages. The results can be seen in the curve of Figure 4. The null inclination angles shown are only relative to each other since the null position can be found only by noting the physical position which provides a zero output voltage from the bridge. In other words, the vertical axis of the "Y"-shaped envelope (See Figure 1) does not correspond to the vertical symmetry axis of the filament. Therefore, locating the symmetry axis of the glass envelope would be of no value. This curve suggests a certain degree of null stability. about 9.6 volts excitation. This feature of the Convectron would require 1% control of the bridge voltage.

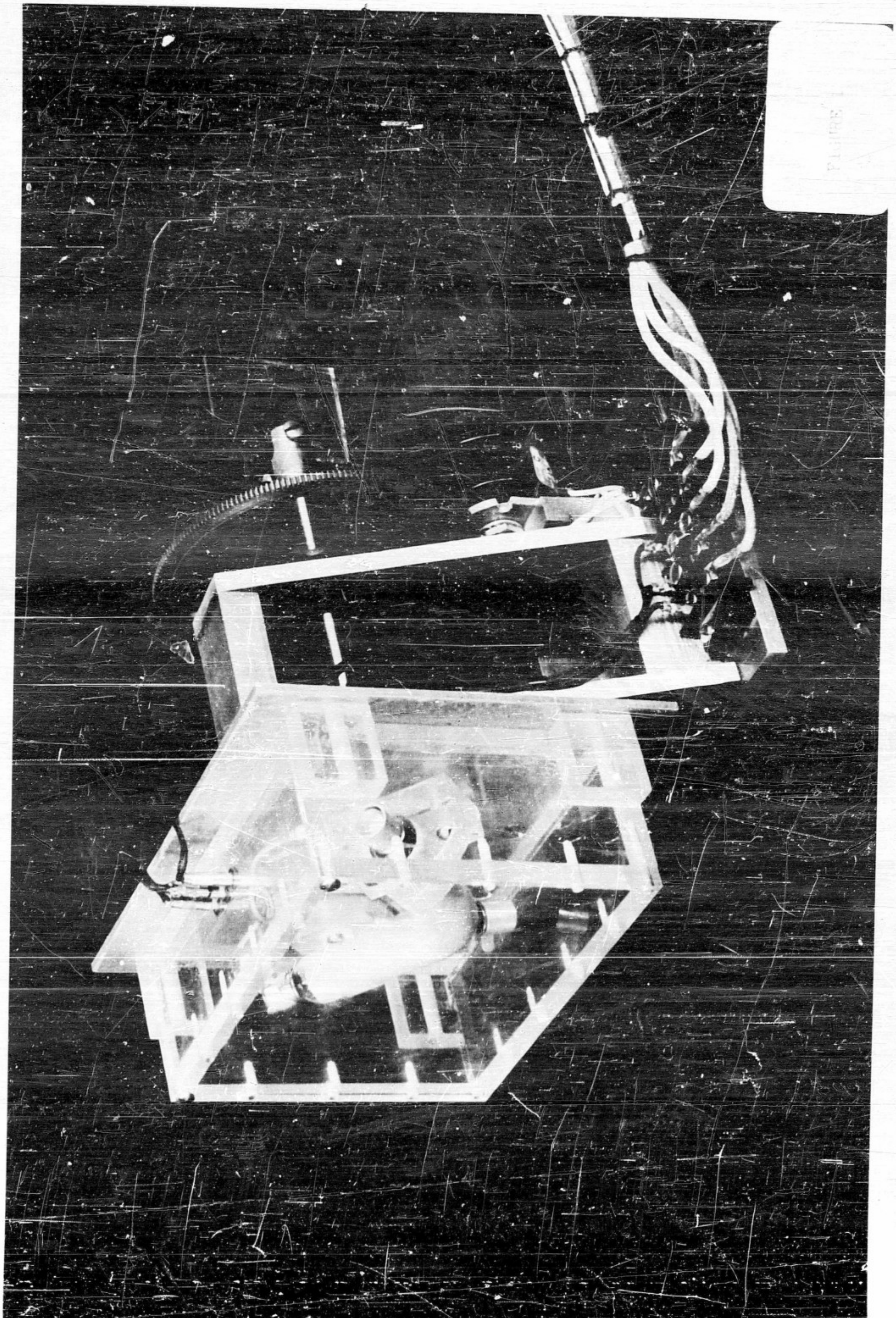
This voltage (9.6 volts) was used for the next test, wherein the reproducibility of the Convectron output was checked. The Convectron was inclined through the total range of the optical system, and output readings were taken at random over a period of a day. These readings were all plotted in Figure 5, and curves were drawn through the extreme points on both the high and the low output sides. The average width of the band along the horizontal axis is approximately 40 minutes of inclination. This is quite large when one considers the fact that the largest error in water velocity desired corresponds to 3 minutes of inclination over the range of 20 degrees of Convectron inclination.

The stability of the Convectron bridge output seemed very good after a long (30 minutes) warm-up period. In an effort to determine the cause of this lag, the bridge was set up using precision resistors and a high sensitivity (0.11 microampere per c.m.) galvanometer as an indicator. With this arrangement, the smallest galvanometer scale division (1 mm.) corresponded to approximately 0.5 second of arc at the null position. Under these conditions, the galvanometer was read immediately after applying the excitation, and thereafter every minute for 20 minutes. This data is the lower curve of Figure 6.

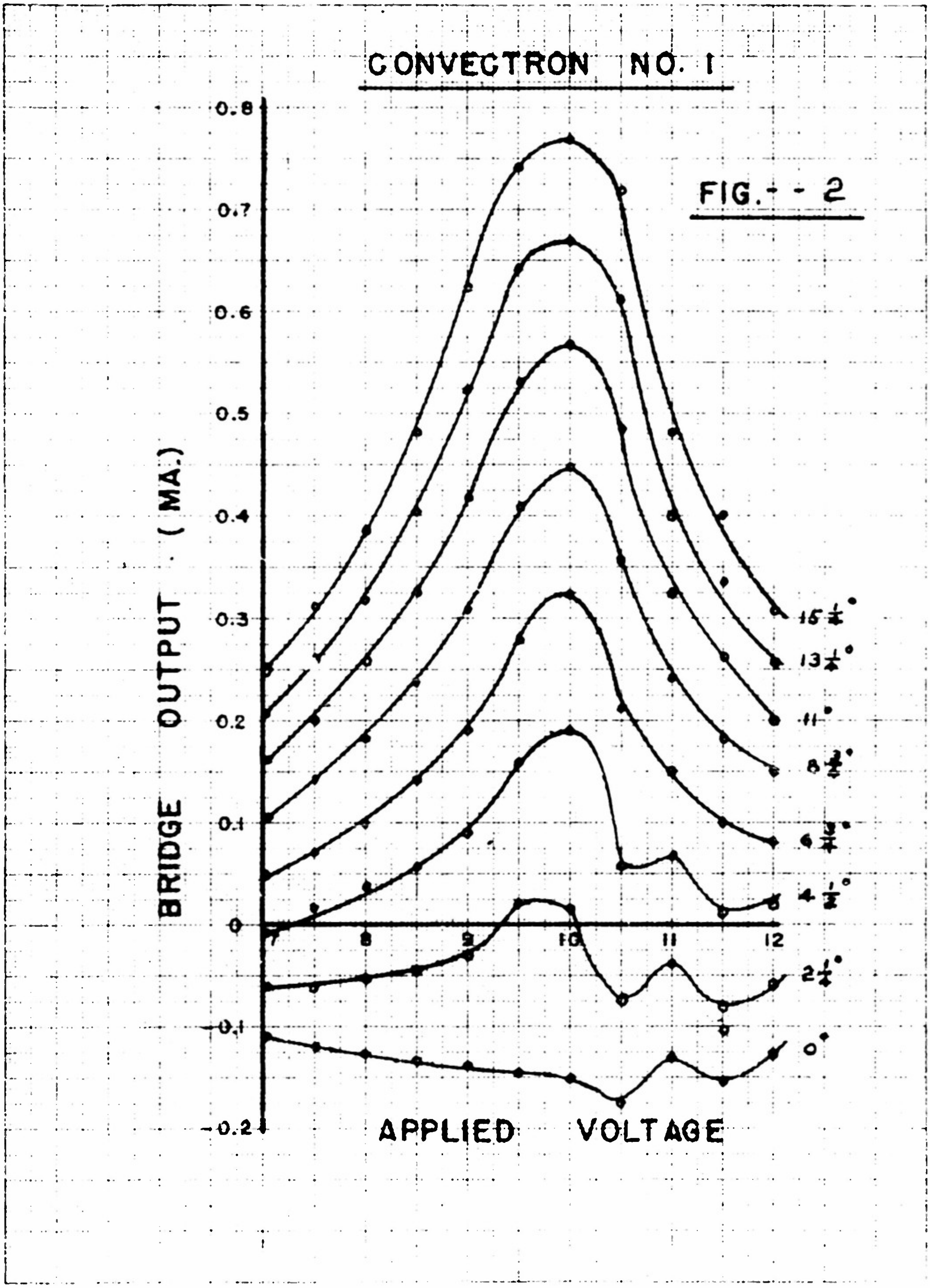
The upper curve of Figure 6 was obtained by duplicating this test after applying a coat of aluminum paint to the envelope. This was done in order to show the effect of the envelope heat dissipation properties. There is not enough difference between these two curves to draw any conclusions.

Conclusions:

The Convectron, as the manufacturer suggests, is a highly sensitive device. It can be used to detect extremely small rotations, but as found by the above tests, it is limited to long period phenomena unless accuracy is a secondary consideration. It would perhaps be desirable to apply it to the measurement of a small range of angles where several minutes were available for each reading, and where precise control could be maintained over the excitation voltage and the ambient temperature.



FIGURE


CONVECTRON NO. 1
FIG. - - 2
BRIDGE OUTPUT (MA.)
APPLIED VOLTAGE
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
7
8
9
10
11
12
15 1/4°
13 1/4°
11°
8 1/2°
6 3/4°
4 1/2°
2 1/4°
0°

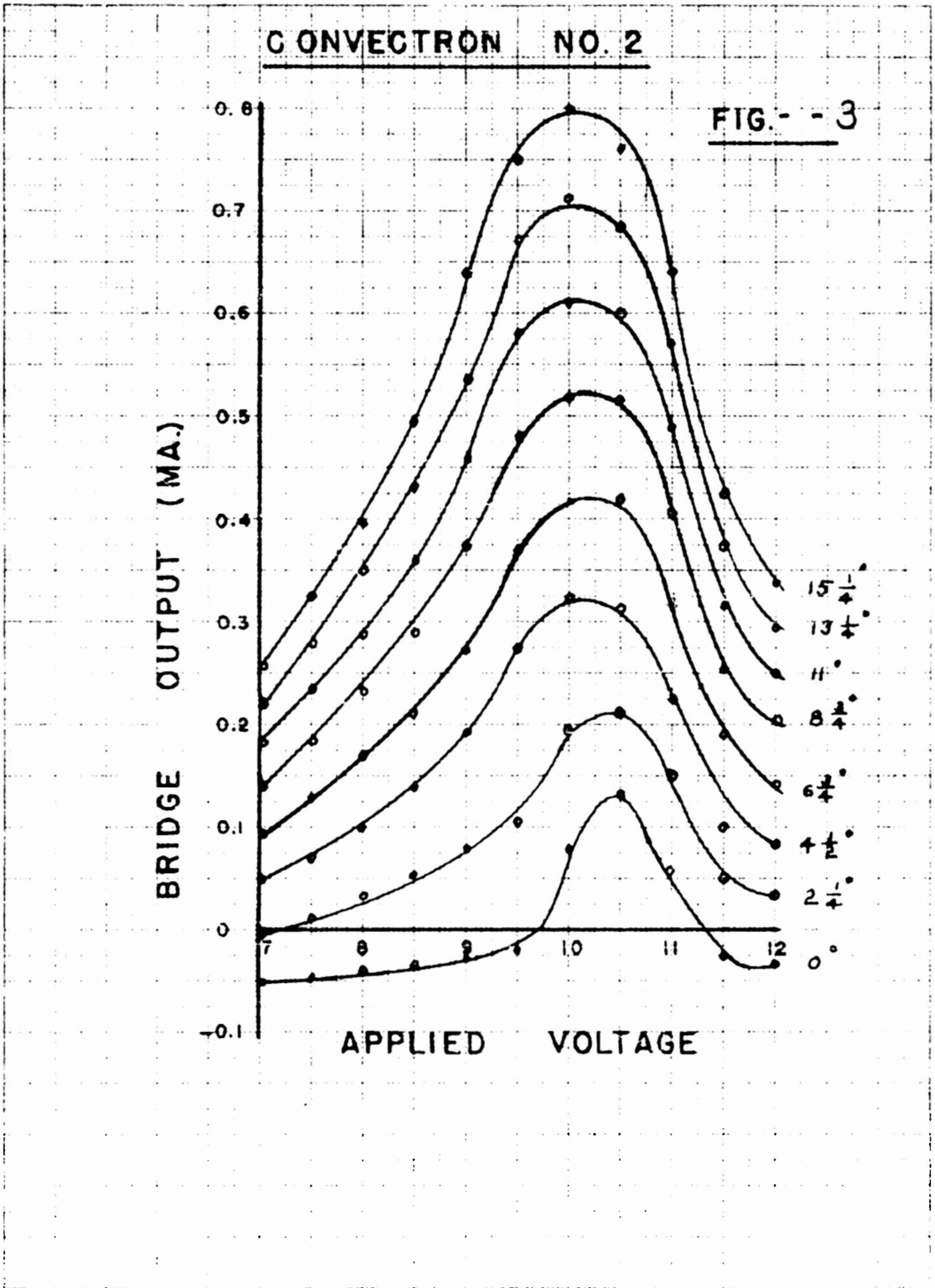

CONVECTRON NO. 2
FIG. - 3
BRIDGE OUTPUT (MA.)
APPLIED VOLTAGE
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
7
8
9
10
11
12
15 1/4°
13 1/4°
11°
8 3/4°
6 3/4°
4 1/2°
2 1/4°
0°

FIG. 4

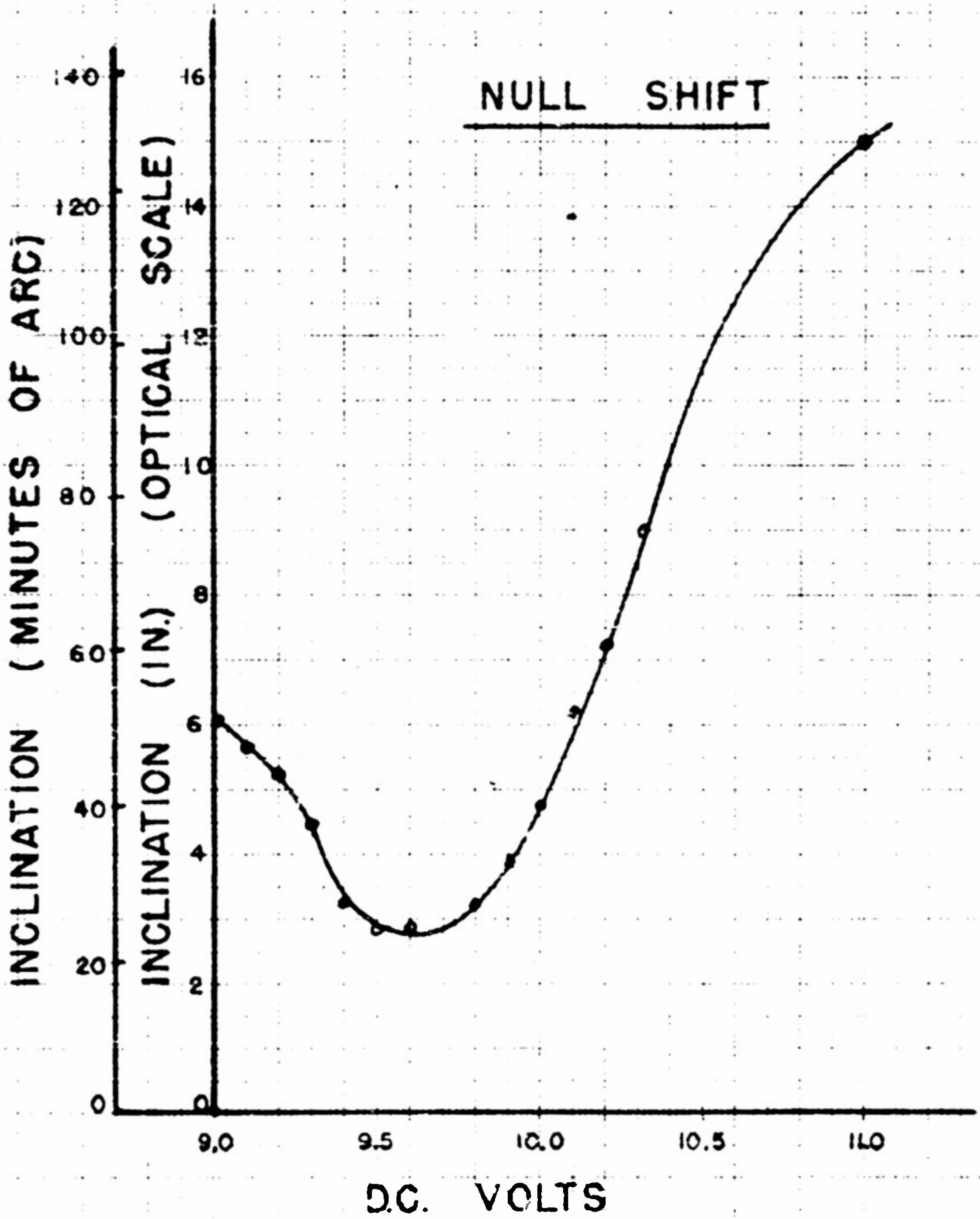
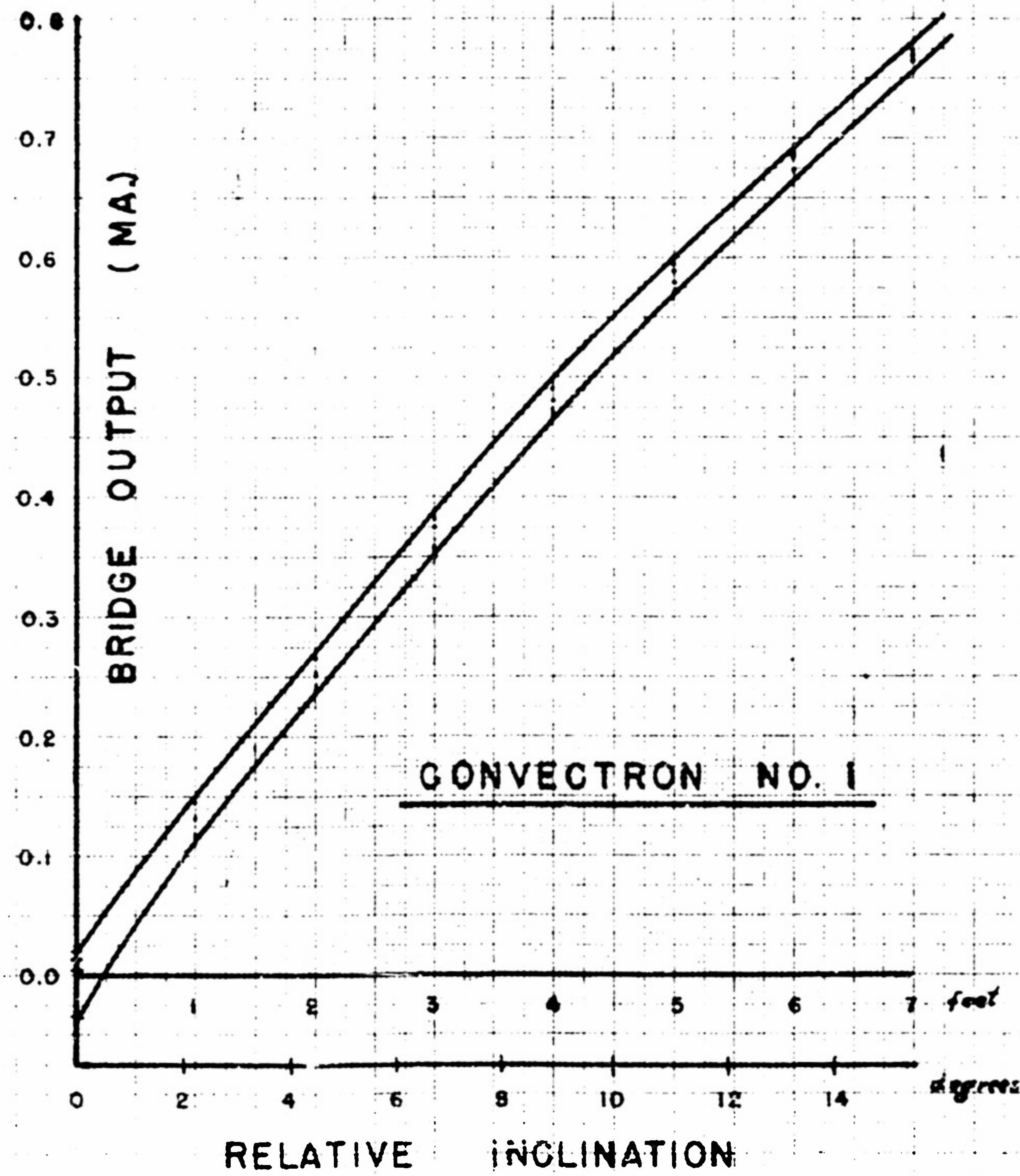

NULL SHIFT
INCLINATION (MINUTES OF ARC)
INCLINATION (IN.) (OPTICAL SCALE)
0
20
40
60
80
100
120
140
0
2
4
6
8
10
12
14
16
9.0
9.5
10.0
10.5
11.0
D.C. VOLTS

FIG. -- 5



0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
BRIDGE OUTPUT (MA)
CONVECTRON NO. 1
1
2
3
4
5
6
7
feet
0
2
4
6
8
10
12
14
degrees
RELATIVE INCLINATION

FIG. -- 6